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OBJECTIVE LENS FOR OPTICAL MEMORY DEVICE  
[Hikari memori sochi yo taibutsu renzu]

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## 1. Title of the Invention

OBJECTIVE LENS FOR OPTICAL MEMORY DEVICE

## 2. Claim

1. An objective lens for an optical memory device comprising a plane surface on one side thereof for emitting a luminous flux opposite of a disk, and an aspherical surface on the other side thereof for receiving a luminous flux reverse to the disk so that the following conditions in ① and ② are satisfied:

$$\textcircled{1} \quad 1.69 \leq n \leq 1.74$$

$$\textcircled{2} \quad n-1 \geq (n_c - n_{A'})/0.00056$$

(where  $n$  is the refractive index of a lens medium for the wavelength of an incident light;  $n_{A'}$  is the refractive index of a lens medium for an A' beam (768.2 nm wavelength) of a refractive light beam; and  $n_c$  is the refractive index of a lens medium for a C beam (656.3 nm wavelength)).

## 3. Detailed Specifications

(Field of Industrial Utilization)

The present invention pertains to an objective lens used in an optical memory device for writing and reading by a laser, and in particular, an objective lens for an optical memory device having excellent chromatic aberration characteristics and abundant practical applicability.

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\*Number in the margin indicates pagination in the foreign text.

(Prior Art)

An objective lens, which has an aspherical surface on one side and a plane surface on the other side, used in an optical disk device is disclosed in, e.g., Tokkai No. 61-88213. If the refractive index of the lens having an aspherical surface on one side and a plane surface on the other side of this type is determined, the central thickness and the variation in its aspherical surface are automatically determined when the sine conditions and spherical aberration are corrected.

(Problems Which the Invention Intends to Solve)

In the objective lens disclosed in the aforesaid Tokkai No. 61-88213, the refraction index  $n$  has a condition of  $n > 1.68$ . However, if we assume, for example, a lens with a diameter of 4.4 mm, at a condition of  $n > 1.68$ , the thickness of the periphery of the lens becomes too thin, and when it is fixed with an adhesive, there is the risk that the effective diameter from the periphery of the lens becomes distorted.

Moreover, in the conventional objective lenses including the lens disclosed in the above-mentioned gazette, a countermeasure for chromatic aberration has not been considered from a manufacturing viewpoint.

In an optical memory device, the light-emitting power for /94 writing information on a disk and the light-emitting power for reading information from the disk are switched. Normally, the light-emitting

power for writing is approximately 30 mW, and the light-emitting power for reading is approximately 2 to 3 mW. However, at present in a semiconductor laser put to practical use, a variation in the wavelength of approximately  $\pm 5$  nm occurs due to switching of the light-emitting power. When the wavelength varies in this manner, a variation in the focal distance occurs due to the difference of the wavelengths for switching from the reading to the writing or vice versa, and the focus servo is offset so a problem arises because the servo becomes impossible to operate.

An object of this invention is to eliminate the above-mentioned problems and obtain an objective lens for an optical memory device which enables sufficient maintaining of the thickness of the periphery, is lightweight, has abundant practical applicability, and can comply with a variation in the laser wavelength due to the switching of the light-emitting power of a semiconductor laser.

(Means Used to Solve the Problems and Operation Thereof)

The present invention is an objective lens for an optical memory device comprising a plane surface on one side thereof for emitting a luminous flux opposite of a disk, and an aspherical surface on the other side thereof for receiving a luminous flux reverse to the disk so that the following conditions in ① and ② are satisfied:

$$\textcircled{1} \quad 1.69 \leq n \leq 1.74$$

$$\textcircled{2} \quad n-1 \geq (n_c - n_a)/0.00056$$

(where  $n$  is the refractive index of a lens medium for the wavelength

of an incident light;  $n_A$  is the refractive index of a lens medium for an A' beam (768.2 nm wavelength) of a refractive light beam; and  $n_C$  is the refractive index of a lens medium for a C beam (656.3 nm wavelength)).

Figure 2 is diagram showing the relationship between the thickness  $t$  of the periphery of the lens and the refractive index  $n$  of the lens medium by calculating that peripheral thickness of the lens when the operating distance of the lens is  $WD$ , the central thickness is  $d$ , and the diameter is 4.4 mm. Moreover, Fig. 3 shows the relationship between the weight of a plano-convex lens having a diameter of 4.4 mm and the refractive index  $n$  of the lens medium by obtaining the weight (mg) of the lens medium with a 3.83 specific gravity by calculating a lens volume from the central thickness of the lens varying in accordance with the variation in the refractive index of the lens medium, assuming that the diameter of the plano-concave lens is 4.4 mm.

First of all, from each of the above-mentioned graphs, the condition that the peripheral thickness of the lens is proper is obtained first. When the periphery of the lens is fixed with an adhesive, the peripheral thickness of the lens must be at least 0.5 mm so as to eliminate the influence of a distortion owing to the anchoring of the lens on the effective diameter. In the diagram in Fig. 2, when a point (a) where the peripheral thickness of the lens becomes at least 0.5 mm is obtained, the refractive index of the lens

at this time is 1.69. Therefore, the following condition (1) is required:

$$1.89 \leq n \cdots (1).$$

Here, the oblique luminous flux characteristics of the light incident to the plano-convex lens will be discussed. Figure 4 shows the relationship between a wavefront aberration (RMS) and a refractive index  $n$  when the inclinations of a parallel luminous flux incident to an objective lens are  $0^\circ$  and  $0.5^\circ$ . As understood from Fig. 4, if the refractive index  $n$  is 1.68 or more, when the inclination of the parallel luminous flux is  $0.5^\circ$ , the RMS of the wavefront aberration becomes substantially constant. Therefore, the condition of the aforesaid equation (1) is required for the oblique luminous flux characteristic.

Next, in order to realize a high-speed access with the objective lens for an optical memory device, it is necessary to reduce the weight of not only an objective lens support part, but the objective lens itself. If the weight of the lens can be reduced to approximately 100 mg or less, it is sufficient to realize a reduction in the weight of a servo movable section in the case of constituting an optical memory device. According to the graph in Fig. 3, the weight of the lens becomes 100 mg when the refractive index  $n$  is set to 1.74. In the diagram in Fig. 2, if the refractive index  $n$  is set to 1.74, the operating distance  $WD$  can be set to 2.0 mm or more. In the optical memory device, the operating distance  $WD$  is approximately

1.8 mm at the minimum so that the disk is not damaged due to a fluctuation in the surface of the disk, displacement of the servo, etc. Therefore, if the refractive index  $n$  is set to 1.74 or less and the operating distance  $WD$  is set to 2 mm or more, the disk can be prevented from being damaged.

In order to satisfy the conditions for both the weight and the operating distance  $WD$ , the following equation is required:

$$n \leq 1.74 \quad \cdots (2).$$

The following condition is determined from this equation (2) and the aforesaid equation (1):

$$\textcircled{1} \quad 1.69 \leq n \leq 17.4.$$

Next, the condition  $\textcircled{2}$  in the present invention relates to /95  
the chromatic aberration, which is the condition relating to dispersion caused by different wavelengths. In the optical memory device as described above, the light-emitting power of the semiconductor laser is switched between one for writing and one for reading, and the wavelength of the laser varies approximately  $\pm 5$  nm. It is necessary with the objective lens for an optical memory device to eliminate the influence of the variation in the wavelength of the  $\pm 5$  nm so that a focusing servo is not influenced. When the lens of the aspherical surface is used as the sole objective lens, the variation in the focal distance of the lens cannot be absorbed by the variation in the wavelength of the laser due to the correction of the aspherical surface. Therefore, according to the condition  $\textcircled{2}$ , conditions are



imparted to the properties of the glass material composing the objective lens to suppress dispersion of the light to the variation in the wavelength. The condition ② will be obtained as follows.

First of all, in Fig. 1, when the focal distance of the lens is  $f$ , the radius of curvature of the aspherical surface 1a is  $r$  and the refractive index is  $n$ , the focal distance  $f$  of the plano-convex lens is represented by the following equation:

$$f = r/(n-1) \quad \cdots (3).$$

The focal distance of the objective lens used for the optical memory device is set to  $f=4$  mm. The refractive index of the lens medium is assumed to be slightly wider range than that of the aforesaid conditions ① ((1) and (2)), and it is considered in the case of  $n = 1.65 - 1.75$ . It is necessary with the plano-convex objective lens having the aspherical surface used for an optical memory device to suppress the variation of the focal distance  $f$  caused by the chromatic aberration of the lens to  $\pm 0.001$  mm or less. If the focal distance varies more than this value, the lens becomes a defocused state due to its relation to the focal depth of the lens, and offset of the focus servo or the like occurs. Therefore, an allowable variation of the refractive index is obtained when the variation in the focal distance becomes 0.001 mm when the focal distance is  $f=4$  mm, as described above.

First of all, the case of  $n=1.65$  will be calculated. When  $n=1.65$  and  $f=4$  mm are substituted into the equation (3), the radius of

curvature of the aspherical surface lens becomes  $r=2.6$  mm. In this case, assuming the focal distance becomes  $f_1 = 4.001$  mm of the allowable limit, the refractive index  $n_1$  at this time becomes:

$$n_1 = (r/f_1) + 1 = (2.6/4.001) + 1 = 1.64983754$$

That is, the variation amount  $\Delta n$  of the refractive index allowed to suppress the variation in the focal distance to 0.001 (mm) of the allowable limit becomes:

$$\Delta n = n_1 - n = 0.0001625$$

In the aspherical surface plano-convex lens having an  $n=1.65$  and  $f=4$  mm, in order to suppress the variation in the focal distance to 0.001 mm of the allowable limit, it is necessary that the variation in the refractive index

$n=0.0001625$ .

calculations

the range of the

index ( $n=1.65$  to

in the following

Table

$n$	$r$	$n_1$	$\Delta n$
1.65	2.6	1.64983754	0.0001625
1.66	2.64	1.65983504	0.0001650
1.67	2.68	1.66983254	0.0001675
1.68	2.72	1.67983004	0.0001700
1.69	2.76	1.68982754	0.0001725
1.70	2.80	1.69982504	0.0001750
1.71	2.84	1.70982254	0.0001775
1.72	2.88	1.71982005	0.0001800
1.73	2.92	1.72981755	0.0001825
1.74	2.96	1.73981505	0.0001850
1.75	3.0	1.74981255	0.0001875

be within

Similar

conducted in

refractive

1.75) are shown

table.

In the above-mentioned table, the variation of the  $\Delta n$  when the refractive index  $n$  varies only by 0.01 (e.g., 1.65 to 1.66) is 0.0000025. This variation is the same with respect to the variations in the refractive indices. Therefore, the variation of the  $\Delta n$  when the refractive index is any given one in the above-mentioned table is as follows: /96

$$(n-1.65) \times 0.0000025 \times 100 \cdots (4)$$

Therefore, from the equation (4), the value of the  $\Delta n$  in case of any given refractive index in the table is as follows, on the basis of  $\Delta n=0.0001625$  when  $n=1.65$ :

$$\Delta n=0.0001625+(n-1.65) \times 0.0000025 \times 100=0.00025(n-1) \cdots (5)$$

This equation (5) is the condition so that the variation of the focal distance  $f$  becomes 0.001 mm when the wavelength of the laser varies by 5 nm due to the switching of the light-emitting power of the semiconductor laser. In order to further generalize this equation, the equation (5) is transformed to correspond to a difference in the wavelengths ( $\lambda_A$  to  $\lambda_C$ )=111.0 nm of the wavelengths  $\lambda_A$ =768.2 nm of the A' beam, which is the reference light beam, and  $\lambda_C$  =656.3 nm of the C beam. Since the equation (5) shows the varied allowable value  $\Delta n$  of

the  $n$  when the variation in the wavelength is 5 nm, when the ratio of the difference  $(n_c - n_{A'})$  in the refractive index  $n_{A'}$  to the A' beam and the refractive index  $n_c$  to the C beam to the  $\Delta n$  is obtained in accordance with the ratio of the wavelengths, the following equation is obtained:

$$(n_c - n_{A'}) / \Delta n = 111.9/5.$$

The following equation is obtained from this:

$$(n_c - n_{A'}) = \Delta n \times 111.9/5$$

Here, since  $\Delta n = 0.00025(n - 1)$  is satisfied, the following equation is obtained:

$$(n_c - n_{A'}) = 0.00056(n - 1)$$

Therefore, in order to suppress the variation in the focal distance with respect to the variation in the laser wavelength within the allowable value, the conditions for the following equation are required:

$$(n_c - n_{A'}) \leq 0.00056(n-1)$$

Therefore, the following condition is obtained:

$$\textcircled{2} \quad n-1 \geq (n_c - n_{A'}) / 0.00056$$

If this condition is satisfied, when the variation in the wavelength is 5 nm, the variation of the focal distance can be suppressed to 0.001 mm or less.

Moreover, the focal distance is set to  $f=4$  mm in the above calculations. However, even if the focal distance is outside of 4 mm, if the above-mentioned conditions in  $\textcircled{2}$  are satisfied, the variation

in the focal distance due to the switching of the light-emitting power of the semiconductor laser can be suppressed.

#### (Practical Examples)

The examples of the present invention will now be described.

The following practical examples is a case shown in Figure 1 in which, in a plano-convex lens having an aspherical surface **1a** on one side and a plane surface **1b** on the other side, the aspherical surface shape is given by the following equation. The following equation is one where the optical axis is on the X axis, and the radial direction of the lens is on the Y axis on the meridional plane of an orthogonal coordinates system, with the vertex of the aspherical surface as the origin.

$$x = (y^2/r) / (1 + \sqrt{1 - (1+K)(y^2/r^2)}) \\ + A y^4 + B y^6 + C y^8 + D y^{10}$$

(where  $r$  is the radius of curvature of the reference-inscribed sphere at the vertex of the aspherical surface,  $K$  is a conical constant,  $A$ ,  $B$ ,  $C$  and  $D$  are quaternary, sexanary, octonary and denary expansion coefficients).

In the following practical examples,  $n$  is the refractive index and  $d$  is the central thickness (mm) of the lens.

#### Practical Example 1

$n=1.69$ ,  $d=1.4296$ ,  $r=2.76$ ,  $K=-0.300068$ ,  $A=-0.144111 \times 10^{-2}$ ,  
 $B=-0.146685 \times 10^{-3}$ ,  $C=-0.810956 \times 10^{-5}$ ,  $D=-0.187406 \times 10^{-5}$

#### Practical Example 2

$n=1.70$ ,  $d=1.5880$ ,  $r=2.80$ ,  $K=-0.285694$ ,  $A=-0.143985 \times 10^{-2}$ ,  
 $B=-0.143215 \times 10^{-3}$ ,  $C=-0.798888 \times 10^{-5}$ ,  $D=-0.176560 \times 10^{-5}$

#### Practical Example 3

$n=1.72$ ,  $d=1.7370$ ,  $r=2.84$ ,  $K=-0.270571$ ,  $A=-0.144145 \times 10^{-2}$ ,  
 $B=-0.140229 \times 10^{-3}$ ,  $C=-0.785993 \times 10^{-5}$ ,  $D=-0.167297 \times 10^{-5}$

#### Practical Example 4

$n=1.72$ ,  $d=1.8830$ ,  $r=2.88$ ,  $K=-0.254381$ ,  $A=-0.144719 \times 10^{-2}$ ,  
 $B=-0.137841 \times 10^{-3}$ ,  $C=-0.772499 \times 10^{-5}$ ,  $D=-0.159751 \times 10^{-5}$

#### Practical Example 5

$n=1.73$ ,  $d=2.0243$ ,  $r=2.92$ ,  $K=-0.238529$ ,  $A=-0.144946 \times 10^{-2}$ ,  
 $B=-0.135254 \times 10^{-3}$ ,  $C=-0.758721 \times 10^{-5}$ ,  $D=-0.152156 \times 10^{-5}$

/97

#### Practical Example 6

$n=1.74$ ,  $d=2.1613$ ,  $r=2.96$ ,  $K=-0.223311$ ,  $A=-0.144722 \times 10^{-2}$ ,  
 $B=-0.132356 \times 10^{-3}$ ,  $C=-0.744761 \times 10^{-5}$ ,  $D=-0.144277 \times 10^{-5}$

#### Practical Example 7

$n=1.75$ ,  $d=2.200$ ,  $r=3.00$ ,  $K=-0.208312$ ,  $A=-0.146773 \times 10^{-2}$ ,  
 $B=-0.130142 \times 10^{-3}$ ,  $C=-0.769152 \times 10^{-5}$ ,  $D=-0.133531 \times 10^{-5}$

(Advantages)

According to the present invention as described above, the peripheral thickness of the lens can be sufficiently ensured, and further, a lightweight lens is obtained. Moreover, the oblique luminous flux characteristics of the lens are excellent, and the operating distance of the lens also can be guaranteed for an optical

memory device.

In addition, the objective lens of the invention can allow for chromatic aberration, and the offset or the like of the focusing servo caused by a variation in the wavelength upon switching of the light-emitting power of the semiconductor laser at the time of writing and reading is eliminated.

#### 4. Brief Description of the Figures

Figure 1 is a cross section showing the objective lens and the disk according to the present invention; Figure 2 is a diagram showing the relationship between the variation in operating distance, central thickness, and variation in the thickness of the periphery of the lens and the refractive index; Figure 3 is a diagram showing the relationship between the variation in the weight of the lens and refractive index; and Figure 4 is a diagram showing the relationship between the oblique luminous flux characteristic and refractive index.

Figure 2

Figure 1

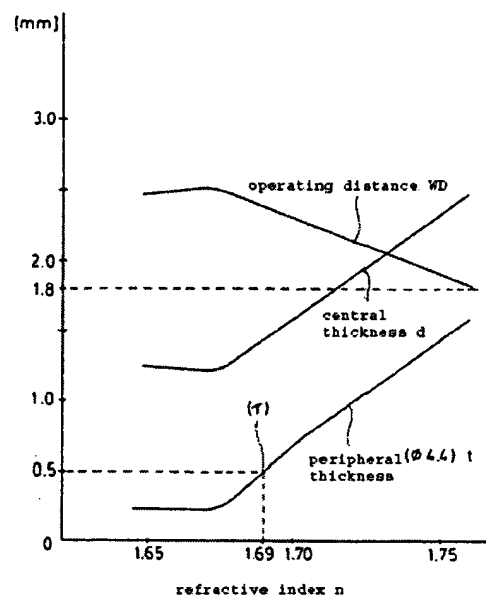
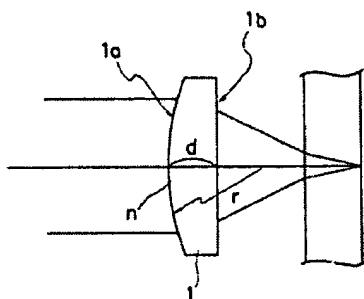




Figure 3

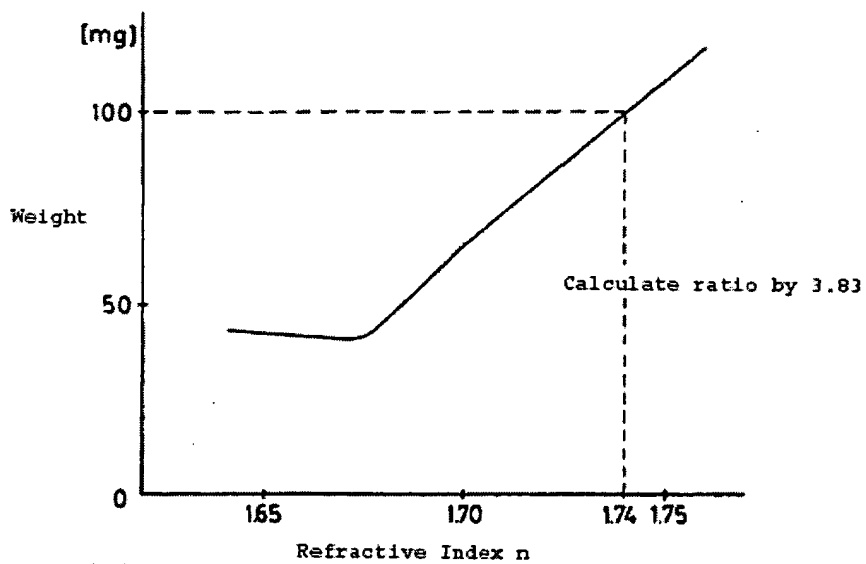


Figure 4

